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Examining Spatial Inequities in Green Space Distribution and Access Around the Historic City of Savannah, Georgia.

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EXAMINING SPATIAL INEQUITIES IN GREEN SPACE DISTRIBUTION AND ACCESS AROUND THE HISTORIC CITY OF SAVANNAH, GEORGIA.

by

CHIAMAKA CHIMAH

(Under the Direction of Meimei Lin)

ABSTRACT

Green space supports recreational activities and environmental sustainability which has proven to aid physical and social well-being as well as environmental health. However, spatial inequities are observed in the distribution and accessibility of urban green space. This norm identified as an environmental justice issue has left racial minorities and people of low socioeconomic status at a disadvantage. This study adopted a geospatial approach to assess green space quantity, quality, and accessibility, and generate a green space index. This research assessed the relationship between racial structure, socioeconomic characteristics and green space inequities in all municipalities in Chatham County, Georgia with a special focus on the historical city of Savannah. Findings revealed that the quantity of green space was considerably higher in the city of Savannah compared to the surrounding municipalities. Green space quality was relatively higher in the northwest of the County, including cities of Bloomingdale, Port Wentworth, Tybee Island and Pooler. On average, Chatham County residents were expected to travel 5.9 miles to access their local green spaces which was significantly better than the national average (6.7 miles) for residents in the United States. The Ordinary Least Squares (OLS) regression model showed that green space inequities in the study area were significantly related to median gross rent and median housing age. However, there were no significant correlations between green space inequities, people of color and low socioeconomic status in Savannah. Future efforts should be directed towards examining spatial inequities in the distribution of green space amenities and its effect on social access to green space.

INDEX WORDS: Green space, Spatial inequities, Accessibility, Savannah, Spatial analysis

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CHAPTER 1

INTRODUCTION

1.1 Background

Environmental justice is a movement that dates to the late 1980s carried out by people of color and minority groups to voice marginal treatment and demand equal environmental opportunities and living conditions. This movement advocates for the fair treatment and meaningful involvement of all people regardless of race, colour, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies (United States Environmental Protection Agency, 2019). This motion gained attention in 1982 when Warren County in North Carolina, a predominantly minority community, was chosen as the location for toxic landfill sites. Several issues after this showed the unfair treatment of low-income groups and racial minorities (Beena and Gupta, 1997; Boone et al. 2009).

In a bid to curb this societal problem, President Bill Clinton signed an executive order in 1994 mandating land management agencies to consider environmental justice regardless of racial and economic status in their decision making (Wolch et al, 2014; Tarrant and Cordell, 1999). While government intervention was observed to have brought positive attention to the issue of environmental justice, several studies have revealed that environmental justice is an issue that plagues access and use of green spaces and park amenities in various neighborhoods (Dai, 2011; Boone et al, 2009; Comber et al, 2008; Wolch et al, 2005; You, 2016; Rigolon and Flohr, 2014; La Rosa, 2014; Nesbitt et al, 2018).

Several environmental justice studies have explored the effect of green space inequities on residents' access to and availability of parks, recognizing the effect on individual recreation and physical well-being (Dai, 2011; Boone et al, 2009). This study examined spatial inequity from an environmental injustice standpoint, to highlight a lack of fairness and injustice in green space distribution. These inequities often arise from ineffective governance as well as social and cultural exclusion. In many cases, these occurrences can be avoided but require informed research that underscores the spatial pattern and provide the basis for government intervention.

In the United States, spatial inequities are evident in the distribution of green space in various cities (Rigolon, 2017; Dai, 2011). This has resulted in inadequate and poor accessibility of urban residents, especially minority groups, to urban facilities and resources including green space. This issue has also been influenced by historical development and city planning (Boone et al, 2013; You, 2016; Tu et al, 2018). Environmental justice and green space provision are important societal issues because they contribute to physical well-being, environmental development and environmental sustainability. Hence, this study adopted an environmental justice inquiry to examine spatial inequities in the distribution and access of green space around Savannah, Georgia.

1.2 The importance of green space in the urban environment

Environmental justice is a community's response to spatial inequities. It seeks equal access for all people to adequate and quality environmental resources including green spaces because of the myriad of benefits they offer. Urban green spaces including playgrounds, parks, community gardens, urban forests and natural reserves are vital components of the urban environment because they connect human beings with nature and contribute to the sustainability of the environment (Dai, 2011). Green space contributes to public health and physical development, and it is highly effective when distributed evenly across the urban area (Hoffimann et al, 2017; Ngom et al, 2016).

Various studies have explored the importance of green space and its contributions to improve air quality and global climate (Vieira et al, 2018; Nowak et al, 2010). Through photosynthesis, green plants sequester greenhouse gases as well as absorb and offset the concentration of other harmful atmospheric gases in the atmosphere. This not only improves air quality but reduces the ambient temperature and has the potential to curb the urban heat island effect (Deilami et al, 2018; Kleerekoper et al, 2012). Besides, urban green space promotes environmental sustainability because green plants can reduce potential flooding by absorbing surface runoff and through stemflow supported by trees. By absorbing surface runoff and stemflow, urban trees prevent the hydrologic consequences of impervious surfaces which limit surface water absorption and contribute to sea-level rise (Puigdefábregas, 2005, Nowak et al, 2020).

Among several ecosystem services provided, urban green spaces also have economic benefits that arise from energy cost savings. In urban housing, the high cost of energy resulting from heating and cooling demands is significantly reduced by the presence of green trees (Donovan and Butry, 2009). This results in energy savings for urban residents and less greenhouse emissions in the environment. When effectively managed, green space can enhance the aesthetic quality of the urban environment that would increase the real estate value of the landscape and scenery (Mansfield et al, 2005).

Urban green space can improve the quality of life in the urban environment. People are drawn to areas with good tree cover compared to areas without for reasons including aesthetics and favorable ambient temperature. Green space in and around schools positively improves the performance of students and their cognitive function (Matsuoka, 2010; Kweon et al, 2017). Studies also show that green space can relieve stress and mental fatigue, and positively affect the decision of high school students to attend a four-year college (Matsuoka, 2010).

Assessing the spatial distribution of green space can provide valuable insight on the geographic location, determine if there is a coincidence of environmental inequities and if green space in low socioeconomic and under-served communities is inadequate. Such information can help better understand and tackle problems such as obesity, crime, individual productivity, and mortality risks.

1.3 Objectives

The goal of this study was to assess the association between socioeconomic status, racial composition of urban residents and green space inequities around Savannah, Georgia. The spatial inequities of green space in the Savannah area were determined based on three variables including quantity, quality, and accessibility. The first objective was to determine the quantity, quality and accessibility of green space around Savannah. The second objective was to assess the correlation between demographics, socioeconomics, and green space inequities of the study area.

In this study, I hypothesized that green space inequities are related to the socioeconomic status of the population and that racial minorities have higher green space inequities. It's further hypothesized that a significant difference exists between spatial inequity in the historic districts and other neighborhoods in Chatham County, Georgia.

This study considered green space quantity, quality and accessibility as indicators of green space inequities. However, it does not consider green space use due to a relatively large case study under review. Also, the study does not address the social function of green space. In addition, this study is limited to accessible green spaces and does not include wetlands or forest reserves.

CHAPTER 2

LITERATURE REVIEW

2.1 Urban green space and spatial inequities

Research on the spatial distribution of public amenities, especially green space, has increased over the last few decades. Several studies have assessed this spatial distribution at different geographic levels to better understand how they relate to the racial/ethnic composition and socioeconomic status of the residents. Environmental justice studies have varied depending on the green space variables chosen, the scale of analysis, or statistical analysis required (Tarrant and Cordell, 1999; Cohen et al., 2013). The majority of studies have assessed inequities by combining one or more of these variables: proximity/accessibility, acreage/quantity, and quality (Table 2.1). The study area adopted by most studies varied widely, ranging from country (Wen et al., 2013; Zhang et al, 2011), state (Moore et al., 2008), metropolitan area (Boone et al., 2009), and to city (Rigolon and Flohr, 2014; Dai, 2011; Comber et al., 2008). These studies adopted various scales of analysis including census tract, census block groups and neighborhoods, depending on the size of the study area.

Table 2.1 Relevant studies on green space inequities

Variable	Relevant Studies
Proximity/Accessibility	Dai, 2011; Boone et al., 2009; Comber et al., 2008; Wolch et al., 2005; You, 2016; Wen et al., 2013; Rigolon and Flohr, 2014; La Rosa, 2014; Nesbitt et al., 2018
Acreage/Quantity	Cohen et al., 2013; Boone et al., 2009; Comber et al., 2008; Wolch et al., 2005; Wen et al., 2013; Moore et al., 2008; Talen & Anselin, 1998; Weiss et al., 2011
Quality	Cohen et al., 2013; Rigolon and Flohr, 2014; Moore et al., 2008; Weiss et al, 2011; Bruton and Floyd, 2014

Data analysis in environmental justice studies encompassed a broad range of spatial analysis in GIS and aspatial analysis including surveys and statistical analysis. Therefore, it is important to consider both the spatial and non-spatial components of green space inequities in an environmental justice study. Thus, this study aimed to highlight spatial trends in green space distribution for the study area and determine their aspatial relationship to the demographics and socioeconomic status of the population.

2.2 Green space quantity

Green space quantity considers the ratio of green space supply to population demand within a geographic unit. A common measure is to determine the acre(s) of available green space for every 1000 people based on a distance buffer around a pre-defined area or by a measure of the nearest neighbor to a local green space. Previous studies reported that groups of low socioeconomic status and racial minorities, the United States, in particular, have access to fewer acres of green space (i.e., parks) when compared to the population size (Boone et al., 2009; Talen & Anselin, 1998; Wen et al., 2013; Moore et al., 2008; Weiss et al, 2011). However, in a four-city study of Albuquerque, Chapel Hill/Durham, Columbus and Philadelphia, Cohen et al. (2013) observed that park acreage was similar in both high poverty and low poverty neighborhoods.

The container method is a straightforward approach used to measure the availability and density of green space within a defined geographic boundary (Talen & Anselin, 1998). Green space quantity is determined by calculating the sum of green space acres available within a geographic area as a function of the total population within the same area. A common approach is to create buffer(s) of the specified threshold around the place of residence (e.g., census block group or census tract), depending on the scale of analysis in the study (Rigolon, 2017). The buffers are then used to determine the amount of green space that falls within the pre-defined area as compared to the total population.

Another approach is to determine the nearest neighbor (green space) to the population (census tracts, block group or neighbourhood) within a specified distance. The point distance determines the quantity of green space from the origin (place of residence) to the destination (green space) using either Euclidean distance or distance along a network (i.e., road network) (Talen & Anselin, 1998; Talen, 2003). These methods use a distance threshold specified to represent walking distance or driving distance/time along a network, to the nearest green space. This measure provides insight on available green space in terms of size/acreage, the potential green space use which indicates the population demand for each green space, as well as green space pressure which indicates the population density for each green space service area.

2.3 Green space quality

The quality of green space is an important consideration that encompasses the amenities, maintenance (Weiss et al., 2011), and vegetation cover (Rigolon, 2017; Nesbitt et al., 2019) in a green space. To assess the availability and quality of recreational facilities and structures, studies often adopt a qualitative approach, such as surveys to assess the availability and quality of recreational facilities and structures (Rigolon and Flohr., 2014; Weiss et al., 2011; Bruton and Floyd, 2014). Several studies have observed that the quality of green space especially park facilities and tree canopy cover was more favorable in neighborhoods with high socioeconomic status (Rigolon and Flohr., 2014; Moore et al, 2008). While other studies found that neighborhoods of minority groups and people of low socioeconomic status had inadequate and poorly maintained recreational facilities (Moore et al., 2008; Talen and Anselin, 1998).

However, Weiss et al. (2011) in their New York study asserted that besides socioeconomic status, ethnicity affects green space quality. They concluded that areas with a high percentage of African American and Latino residents had significantly more park features with a wider variety of park facilities. In examining spatial inequity of green space, the relationship of green space quality to socioeconomic status and ethnic composition of residents in a neighborhood varies based on the study area and scale of analysis, thus have resulted in mixed findings.

Vegetation cover has also been used as an indicator of quality, to determine potential social access to urban green space based on its environmental benefits of providing shade and safety (Kuo & Sullivan, 2001). A common approach to assess vegetation cover in environmental justice studies involves Digital Image Processing (DIP). The National Agriculture Imagery Program (NAIP) dataset is commonly used because it provides freely downloadable high-resolution imagery with a broad spectral range. The NAIP imagery provides imagery at 95% confidence level, the optimum level of accuracy. The Normalized Difference Vegetation Index (NDVI) has been computed to represent vegetation health and determine vegetation type (Nesbitt et al., 2019).

Several studies also use the NAIP imagery to estimate vegetation cover from supervised and/or unsupervised image classification techniques (Zhou and Kim, 2013; Nesbitt et al, 2019). The NDVI index has also been used to classify vegetation cover into various types such as mixed vegetation and woody vegetation (Nesbitt et al, 2019). This method, in addition to a supervised or unsupervised classification uses the index range of NDVI to specify the vegetation type, thereby improving classification accuracy. An accuracy assessment is performed after the image classification to determine the efficiency of the classification method in grouping pixels into the right classes (Zhou and Kim, 2013; Nesbitt et al, 2019).

Using the NAIP imagery to determine spatial inequities, Nebitt et al. (2019) observed a positive relationship between the White population, per capita income, higher education and vegetation cover across ten US cities. However, a negative correlation was found when vegetation cover was compared to the proportions of Black and American Indian. Similarly, in a study of six cities in Illinois, Zhou, and Kim (2013) reported a consistent negative relationship between tree canopy cover and the proportion of African American residents in five cities. When tree canopy cover was compared for residents with a bachelor's degree and higher, they also found a greater tree canopy distribution in these neighbourhoods. To assess public green space quality in Shenzhen, China, You (2016) used different landscape fragmentation metrics, defining low quality green spaces as highly fragmented areas and vice versa. So far, there is no generally accepted method(s) adopted to analyze green space quality. Instead, measures are often tailored to individual studies based on the author's discretion of best fit.

2.4 Green space accessibility

Green space accessibility/proximity is a measure of how accessible the closest green space is to a home, usually based on a threshold that represents the walking distance or driving time. The Trust for Public Land sets the acceptable walking distance at half a mile (ten-minute), entirely within the public road network and without physical hindrances such as railroads, highways and rivers (Trust for Public Land). Other organizations including the National Recreation and Park Association (NRPA) and Urban Land Institute (ULI) advocate for this 10-minute walking distance because it supports the recreational needs of the population, especially the young and elderly who are less likely to have access to vehicles.

Findings on green space accessibility varied depending on the scale of inquiry. Nevertheless, studies have found that minority groups and those of lower socioeconomic status had poor access to parks, and thus had to travel long distances from their places of residence to use green spaces (i.e., parks) (Dai, 2011; Comber et al, 2008; Rigolon and Flohr, 2014; You, 2016; Wolch et al, 2005; Nesbitt et al, 2018). However, Wen et al. (2013) in studying the urban–rural continuum in the conterminous USA observed that spatial access to parks in rural areas was not necessarily affected by poverty as was observed in the urban areas. This study also underscores the importance of race as findings showed that census tracts with higher poverty and higher percentage of Blacks or Hispanics had less access to green spaces in the urban areas; however, this situation was not common in rural areas.

A common approach of green space accessibility is distance analysis, based on point distance, using Euclidean or network distance to measure green space accessibility (Wolch et al, 2005; Nesbitt et al, 2018; Dai, 2011; Weiss et al, 2011). In network distance, access to green space from a place of residence is calculated on a network (i.e., road network) (Comber et al, 2008; Bennet et al, 2012; Rigolon and Flohr, 2014). Using network distance often results in a long distance from the origin to destination when compared to Euclidean (straight-line) distance because it follows the road network. However, it is arguably more accurate, especially when driving time and distance is the focus because it considers important factors like intersections, speed limit, and traffic.

The gravity model is another commonly used measure for determining spatial accessibility. This method sums green spaces within a pre-defined region based on the distance between the green space and the region (place of residence), as a travel friction (Dai, 2011). The travel friction examines the cost of traversing from a fixed point to another, taking into consideration distance, and perhaps time. To determine the accessibility of the total population to a green space, the travel friction considers the population a major element and thus is weighted based on the distance of the population (from their places of residence) to the green space. This population weighted distance method is commonly used to indicate access to facilities or amenities based on the shortest straight-line (Euclidean) distance between the place of residence, and the size of the green space. This is used to compare access to several green spaces and determine potential population pressure for each. (Talen, 2003; Zhang et al, 2011). Despite the differences between the two common methods, some studies adopted a hybrid approach that incorporated both the gravity model and distance analysis. In analyzing access to play opportunities for youth in Denver, Riglon and Flohr (2014) adopted a weighted spatial network analysis to measure the minimum distance to parcels from parks and determine the percentage of the population with access.

The two-step floating catchment area (2SFCA) method is another commonly used technique in accessibility studies. This spatial interaction model measures potential access to green space based on a threshold of; travel time or distance (Dai, 2010; James Bryant & Delamater, 2019). Luo and Wang (2003) developed the pioneer method, a gravity model, which is a population weighted approach that considers the ratio of supply (green spaces) to demand (population), weighted by the negative power of travel times. The 2SFCA is an improvement on the gravity model because it considers travel time impedance as dichotomous, attributing equal accessibility to travel time within a specified threshold and equal inaccessibility to travel time beyond the threshold (Luo and Wang, 2003).

2.5 Green space inequities and historical development

Environmental justice studies on green space have shown that the quantity and quality of green space as well as their distribution across cities and neighborhoods were plagued by inadequate consideration for racial minorities and low-income groups compared to racial majorities and high-income groups in urban areas. However, findings from these indicators reviewed still presented mixed results on the advantaged and disadvantaged groups regarding different measures. Nevertheless, several studies have concluded that urban planning and development strategies evident in city plans and design have affected green space inequity significantly. Boone et al. (2009) observed more congestion of parks in African American dominated neighbourhoods but less congestion in predominantly (non-Hispanic) White neighborhoods in Baltimore, Maryland. However, Baltimore residents overall had relatively good access to parks. Their study accounted for the important aspects of the city's historical planning that contributed to city-wide park accessibility, including the effect of segregation in the early 1900s on the city's development.

A similar finding in Beijing, China attributed its distinct results to city planning strategies and historical development of Beijing (Tu et al, 2018). It highlighted the role of city government in managing city development including the provision of green spaces which ensured a certain level of equity in the distribution of public amenities. You (2016) examined green spaces in Shenzhen, China and observed better quality green spaces in districts with housing disadvantage. He found that the city's plans placed the wealthier population in central districts, which were surrounded by commercial lands, and had limited space for greening. Land use plan plays a vital role in city planning and the development pattern of the city. This, in turn influences how public amenities are distributed which set the pace for environmental equity.

In summary, this underscores the need to examine the historical city planning and urban development strategies that affect land use patterns and the spatial distribution of green spaces. This may be useful to explain the dissimilar relationship between green space and race, and socioeconomic status in an environmental justice study.

2.6 Spatial inequity covariates

Research examining spatial inequities of green spaces considers variables that relate to the structure and characteristics of the population. Most studies report socioeconomic variables especially income and education and use them to determine spatial inequities. Factors considered in previous studies also include housing age, median age, median gross rent, employment status and median housing value (Table 2.2). Data on race structure such as White, Black, Latino/Hispanic, were included as confounding variables. Some studies also include minority groups such as Hawaiian/Pacific Islanders and American Indians/Alaska natives. The relationship between these variables and green space distribution/accessibility differs depending on the scale of analysis (block group, census tract or County) and the size of the study area (city, metropolitan area, County, state or country).

Table 2.2 Spatial inequity covariates of related studies

	Covariates	**Related sources**
Socioeconomic variables	Income	Nesbitt et al, 2019; You, 2016; Landry & Chakraborty, 2009; Troy et al, 2007; Wolch et al, 2005; Boone et al, 2009; Moore et al, 2008; Cohen et al, 2012; Dai 2011
	Education	Nesbitt et al, 2019; Schulser et al, 2018; You, 2016; Landry & Chakraborty, 2009; Troy et al, 2007; Maroko et al, 2009; Wolch et al, 2005
	Housing age	Nesbitt et al, 2019; Zhou & Kim, 2013, Grove et al, 2006
	Median age	Nesbitt et al, 2019
	Employment	(Schulser et al, 2018; You, 2016; Dai 2011
	Median gross rent	Dai 2011
	Median housing value	Dai 2011
Race / Ethnicity	White, Black, Asian, Latino/Hispanic, Hawaiian/Pacific Islanders, and American Indians/Alaska natives	Nesbitt et al, 2019; Zhou & Kim, 2013; Bruton and Floyd, 2014; Maroko et al, 2009; Wolch et al, 2005; Boone et al, 2009; Moore et al, 2008; Dai 201

2.7 Current research gap

The literature review showed a gap in relation to green space inequities and historical development. Only a few studies explored the importance of a city's historical development on green space distribution and environmental justice (Boone et al, 2009; You, 2016). In the aforementioned studies, the relationship observed between green space distribution, race and socioeconomic status was affected by the city's history and planning strategies. As the first planned city in the United States, Savannah is unique in its history and city planning. To the author's knowledge, no study has focused on the spatial distribution of green spaces in the city from an environmental justice standpoint. Hence, this study aimed to assess the relationship between socioeconomic status, racial composition of the residents and green space inequities around the historical city of Savannah. The study also recognized the importance of a city's history in green space inequities, thus compared findings from Savannah to findings from surrounding cities in the region with comparatively sporadic city development.

CHAPTER 3

METHODOLOGY

3.1 Study area

The study area is Chatham County, Georgia including Pooler, Port Wentworth, Garden City, Bloomingdale, Vernonburg, Tybee Island and Thunderbolt, as well as the historic city of Savannah (Figure 1). Chatham County lies in southeast Georgia by the Atlantic coast. Savannah is the County seat notable as an Atlantic seaport and for its industrial activities. The Savannah Metropolitan Area (SMA) is Georgia's third largest. It also basks in national recognition as a historical city evident in decades of city planning, architecture and urban design, while its preservation efforts over the years have attracted tourists from around the world.

Chatham County is comprised of approximately 285,506 people based on the 2017 population estimate and has a population density of 1330 inhabitants per square kilometre (United States Census Bureau, 2017) (Figure 1). It includes a total of 205 block groups, but only 202 of the block groups were used due to data unavailability. There are 187 green spaces classified by the Savannah Area Geographic Information System (SAGIS) as public green space, community parks and playgrounds, piers/boat ramps, preservation/nature and sports/recreation. Green spaces included in this study are public green space, community parks and playgrounds, sports and recreation. Hence, a total of 164 parks were included and they are under the jurisdiction of Chatham County, cities of Savannah, Pooler, Port Wentworth, Bloomingdale, Tybee Island, Thunderbolt and Garden City (Figure 1).

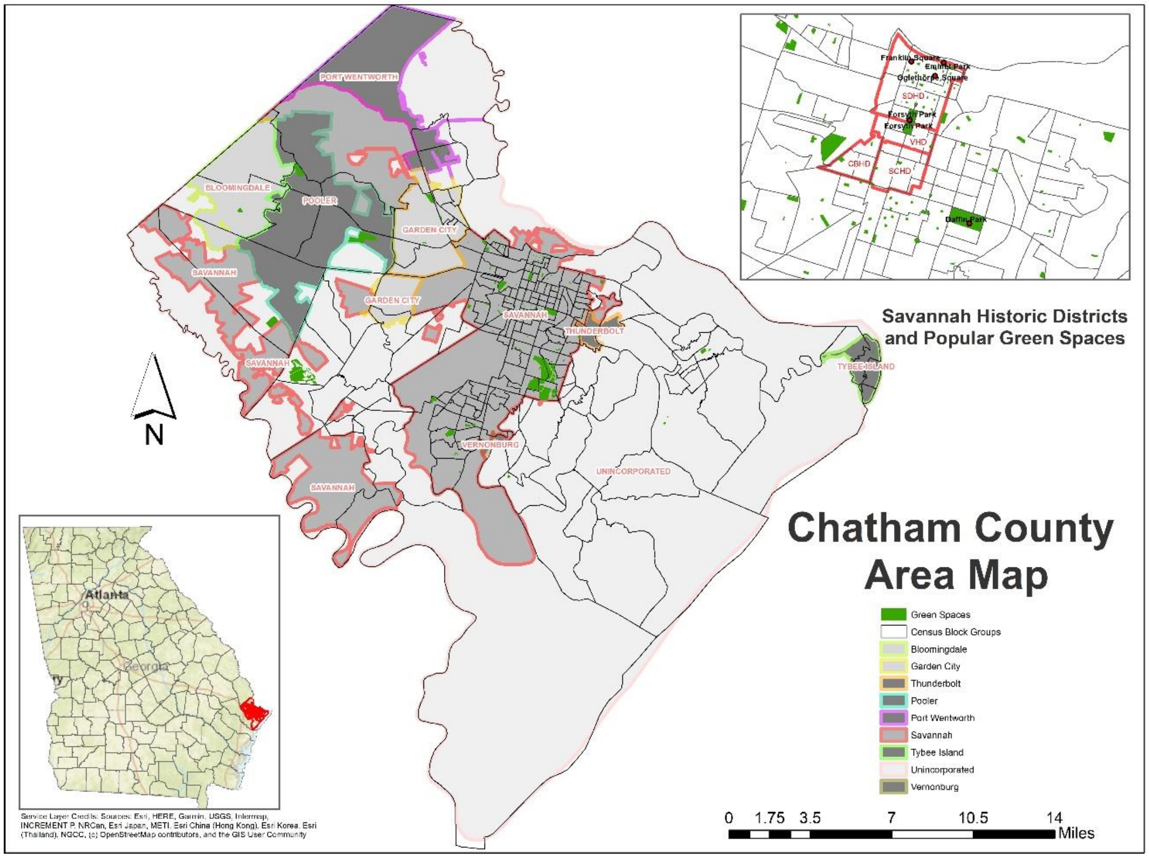

Figure 1: Chatham County area map including its municipalities and the distribution of green space around the city of Savannah, other municipalities in Chatham County and Savannah's historic districts.

In the 1970s, Savannah's preservation efforts contributed to revitalization and rehabilitation of the city's structures. However, some of this had negative impacts on the economic and social structure of the city, resulting in gentrification as high rent and property values forced low-income households out of the preserved neighborhoods (Hodder, 1993). Under-served groups, like African Americans, were also negatively affected by the preservation movement. While many of the preservation initiatives were carried out in Black-dominated areas, African American residents continuously moved out from the historic core and across several neighborhoods due to a fast-changing real estate market (Hodder, 1993). As such, preservation efforts in Savannah reflected a social dominance of White culture with no or little concern for low-socioeconomic groups, especially African Americans. In response to this, Savannah Landmark Rehabilitation Project (SLRP) was founded in 1975 to mitigate the effects of gentrification, especially in the Victorian District where Black and low-income residents were adversely affected by preservation efforts. This group sought to resolve this crisis by providing financial assistance to current residents and undertaking the rehabilitation of deteriorated houses in historic neighborhoods as a non-profit group. Several other contributions were made to reduce the marginalization of African Americans by individual groups and organizations like the Beach Institute neighborhood that provided financial resources in the 1980s for Blacks to be part of the historic district (Hodder, 1993).

Savannah has four nationally recognized historic districts downtown; Savannah downtown historic district (SDHD), Victorian historic district (VHD), Streetcar historic district (SCHD) formerly Mid-city district and Cuyler Brownville historic district (CBHD) which contribute to its rich planning history (Figure 1).

The planning history of Savannah differentiates it from surrounding urban and sub-urban areas. This has a positive effect on the distribution of urban facilities, including green spaces in the region. The city has housing and public amenities carefully laid out in grids with 24 squares initially built to serve as public spaces. These squares are a major part of Savannah's history, pioneered by James Oglethorpe, the founding father of the city who developed six at the inception. Other squares sprang up from the early 1700s while the majority were developed in the late 18th century and 19th century. There are currently 22 squares around the city because two were lost to city development. Today, these squares serve as major green spaces in the city, supporting the recreational activities of Savannah's residents and its tourists.

3.2 Some major green spaces in Chatham County, Georgia

Green space in the study area is classified either as public green space, community parks, and playgrounds or sports and recreation. The following examples explain this classification using some major green spaces and provide context on green spaces in Chatham County, Georgia.

3.2.1 Forsyth Park

Forsyth Park is the largest and oldest park in the historic district of Savannah. It was initially developed in the 1840s on 10 acres of land donated by Willian Hodgson but was expanded in 1853 and named after the Georgia governor, John Forsyth (Savannah Highlights). The park classified as a community park and playground is owned and maintained by the city of Savannah. In Chatham County, community parks and playgrounds span a considerable area of land and host several play opportunities for residents. Presently, Forsyth Park spans 30 acres of land and houses the confederate memorial, a theatre, several tennis, and basketball courts. The park also provides two playgrounds to support recreation and adequate room for sports and events. The fountain is also a famous attraction for residents and tourists making it one of the most photographed places in the city.

Figure 2: Forsyth Park

3.2.2 Daffin Park

Daffin Park is a historic city park that supports sports and recreation for the city's residents. It is notable as Savannah's first significant twentieth-century green space (Savannah government). This Beaux Arts inspired park designed in 1907 was named after the first chairman of the Savannah Park and Tree Commission, Phillip Daffin whose office was assigned management of the park by Savannah's city council (Savannah Highlights). As with other green spaces in Chatham County classified as sports and recreation, Daffin Park spans a wide area of land and caters to a large proportion of urban residents by providing some form of sports and/or recreation attraction. Daffin Park spans about 80 acres of land and is home to Savannah's Grayson Stadium, supporting several field activities especially baseball. Located to the southeast of Savannah's downtown historic district, this park also offers a public pool, pond and walking path.

Figure 3*: Daffin Park*

3.2.3 Emmet Park

Emmet Park is also a popular park located in the historic district of Savannah. It spans about 4 acres with notable attractions like the old harbour light, a rear range light placed in the mid-19th century at the eastern end of the park to provide navigation aid to ships. It also includes historic relics and memorial to soldiers and military organizations from the city's inception till today. The park was named in 1903 and built in memorial of Robert Emmet (1178-1803), an Irish patriot (Savannah highlights). This park plays a major role in the history of Savannah's Irish population. The famous park-like Forsyth Park is classified as a community park and playground, owned and managed by the city of Savannah. Its green space supports recreational activities for both city residents and tourists with areas to relax, sit and engage in sports.

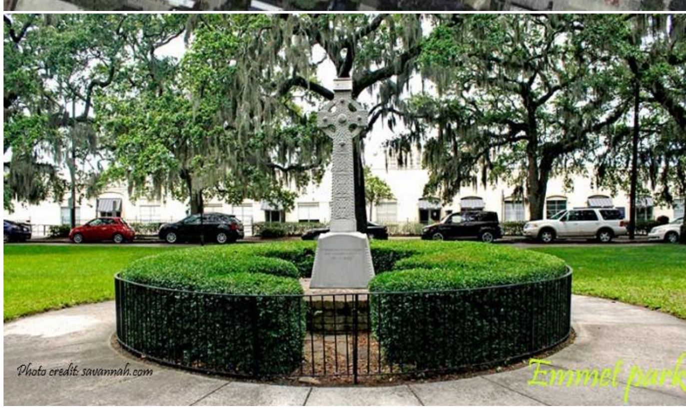

Figure 4: *Emmet Park*

3.2.4 Oglethorpe Square

Oglethorpe Square is one of the six squares planned by James Oglethorpe in the 1730s. This square was established last of the six squares in 1742 as Upper New Square, but it was eventually renamed after Georgia's founder, General James Oglethorpe (Savannah highlights). The square houses a monument for

Moravian missionaries who settled in the city from 1735 to 1740. It is also home to the popular Owens-Thomas house, a notable historic house in the city that currently serves as a museum for public use. Located in the north-east central part of the historic district, the square spans roughly one acre of land. Oglethorpe Square is classified as a public greenspace, owned and managed by the city of Savannah. Public green space in Chatham County is relatively small green spaces with less play amenities compared to other types of green space. However, with benches laid out on its walkways, under tree shades, it serves as a relaxation area for residents and tourists.

Figure 5: *Oglethorpe Square*

3.2.5 Franklin Square

Franklin Square was planned and laid out in 1790, after the first six squares. It was named in 1791 for Benjamin Franklin who was an agent for the colony of Georgia from 1768-1778 (Savannah highlights). The square is owned and managed by the City of Savannah and is located on the western end of the city and spans a half-acre in the historic district. Like Oglethorpe Square and other public green space in the study area, Franklin Square has limited play amenities but historic monuments that serve as tourist attractions. The square was destroyed in 1935 due to highway construction but was rebuilt in the mid-1980s. It is home to a memorial unveiled in 2007 in honor of Haitian volunteers who fought during the "Siege of Savannah." The square is classified as a public green space by the city and supports the recreational activities of the residents and tourists.

Figure 6: *Franklin square*

3.3 Data sources

Demographic and socioeconomic data including race/ethnicity, median income, education, median gross rent, median housing value, housing age, and employment status were downloaded from the United States Census Bureau's decennial census program (Schusler et al, 2018; Rigolon et al, 2018; Nesbitt et al, 2019) (Table 3.1). The data obtained are 2017 5-year estimates collected at the block group level for Chatham County, Georgia (Table 3.1). Block group data is the smallest geographic unit at which sample data is collected by the bureau, and it represents about 600 – 3,000 people which may be identified as a community (United States Census Bureau, 2019). Data at the block group level (also referred to as neighborhoods in this study) provides a finer scale for the analysis of environmental inequities compared to the geographic scales used in previous studies (Nesbitt et al, 2019; Troy et al, 2007; Dai, 2011). In addition, such level of details can improve the precision of accessibility measure, defined as walking distance (Talen, 2003). This study focused on all races including Native Hawaiian/Pacific Islanders and American Indians/Alaska natives grouped as a minority because they collectively make up ~2.77% of the total population.

Table 3.1: Detailed description and data sources of all spatial and nonspatial variables including racial and socioeconomic covariates

Data Type	**Variable**	**Description**	**Data Source**
Spatial	Green space	This includes public green space, parks, playgrounds, sports and recreation centers	Savannah Area Geographic Information System (SAGIS)
	National Agriculture Imagery Program (NAIP)	This is a 1m high resolution aerial image which depicts geographic features of Chatham County in 4 spectral bands (blue, green, red, near infrared)	DigitalCoast The National Oceanic and Atmospheric Administration's (NOAA) Office for Coastal Management
Aspatial	Median income	This is the estimated average income of residents in each neighborhood	United States Census Bureau (American Community Survey) 2017 5-year estimates
	Education attainment	This is the percentage of residents in each block group with a professional degree, college degree or post-college degree	United States Census Bureau (American Community Survey) 2017 5-year estimates
	Employment status	This is the percentage of the labor force employed in each block group, including military and civilian	United States Census Bureau (American Community Survey) 2017 5-year estimates
	Median housing age	This is based on the year the housing structure was built. It represents the average age of structures in each block group	United States Census Bureau (American Community Survey) 2017 5-year estimates
	Median gross rent	This is the estimated gross rent of structures in each block group	United States Census Bureau (American Community Survey) 2017 5-year estimates
	Housing value	This is the estimated value of buildings in each block group.	United States Census Bureau (American Community Survey) 2017 5-year estimates
	White (non-Hispanic)	This is the percentage of White residents in each block group with no Hispanic or Latino ancestry	United States Census Bureau (American Community Survey) 2017 5-year estimates
	Black(non-Hispanic)/ African American)	This is the percentage of Black/African American residents in each block group with no Hispanic or Latino ancestry	United States Census Bureau (American Community Survey) 2017 5-year estimates

Hispanic/Latino	This is the percentage of residents in each block group with primarily Hispanic or Latino ancestry	United States Census Bureau (American Community Survey) 2017 5-year estimates
Asian	This is the percentage of residents of Asian descent including those with some Hispanic or Latino ancestry in each block group.	United States Census Bureau (American Community Survey) 2017 5-year estimates
Minority	This is the percentage of Hawaiian/Pacific Islanders and American Indians/Alaska natives in each block	United States Census Bureau (American Community Survey) 2017 5-year estimates

3.4 Preprocessing

All datasets for the study were stored and managed in a file geodatabase, transformed into a projected coordinate system (NAD_1983_StatePlane_Georgia_East_FIPS_1001_Feet) based on Transverse Mercator projection and Datum of North America 1983.

3.4.1 Spatial data

The spatial data including Chatham County census block groups, green spaces, municipalities and Savannah historic districts were obtained from Savannah Area GIS (SAGIS) open data portal. This data, available as shapefiles, was directly imported into ArcMap. The features for each dataset were exported as feature classes and included in the file geodatabase for the project.

3.4.2 Aspatial data

In this study, median gross rent, median income, education, employment, median housing value and median housing age were chosen to represent the socioeconomic characteristics of the population. While White (non-Hispanic), Black (non-Hispanic), Hispanic/Latino, Asian and minority population represent the racial structure of the population. These tables were joined to the existing census block group feature class based on their unique identification numbers and the feature class for each variable was saved in the project geodatabase with unique titles.

3.5 Dependent variables

3.5.1 Quantity of green space around Savannah

The quantity of green space is measured as a function of population density and green space acres. Several studies have used the container method as a measure of green space quantity/acreage (Talen and Anselin, 1998). This method assesses green space quantity based on the acreage of green space within each geographic boundary (block group or census tract). This misrepresents available green space because it assumes residents only make use of parcels within their geographic boundary (Rigolon, 2017; Talen, 2003). This study adopted the point distance approach to measure resident's green space acreage within a specified radius. To compute the quantity of green space, three factors were considered in this framework; origin, destination and route characteristics (Talen, 2003). The origin constitutes the place of residence of the population and includes the block groups in this study, represented as centroids. The destination represents the resource; green spaces and is defined by centroids weighted by green space acreage. The route characteristics were determined based on the mode of travel from origin to destination. Here, walking was considered the travel means because it can be easily adapted by all residents, especially the young and elderly. Euclidean distance, which depicts the shortest path from the origin to the destination was adopted. This is because people are more likely to walk in a straight line towards their destination, including a green space, as opposed to walking along a road network.

Mathematically, Euclidean distance is represented as follows:

$$\text{Euclidean distance} = \sqrt{}(x_1 - x_2)^2 + (y_1 - y_2)^2 \qquad \text{(i)}$$

Where x_1–x_2 is the difference between the origin and destination on the x-axis and y_1-y_2 is the difference between origin and destination on the y-axis.

To assess park acreage, two thresholds, 10-minute and 20-minute walking distance, were selected to represent walking distance to green spaces in the study area. The 10-minute walking distance to green space is advocated by several organizations including the National Recreation and Park Association (NRPA), Trust for Public Land (TPL) and Urban Land Institute (ULI). Upon preliminary analysis, less than 5% of the population was covered using this threshold. The population density of the study area is a major determining factor in selecting an appropriate threshold. Densely populated and highly urbanized cities, such as Denver, Colorado and Atlanta, Georgia, are more likely to adopt a smaller threshold (10-minute distance) (Rigolon, 2017; Dai, 2011) compared to sparsely populated cities and towns. Thus, the 20-minute threshold was included because the population density is sparse compared to other studies which adopt smaller thresholds (5-minute).

Green space quantity is measured based on the ratio of green space acreage to the population within the specified radius (Tarrant and Corrdell, 1999; Schule et al, 2017). To assess green space quantity, the Euclidean distance from each block group to the center of the nearest parks within 10-minute and 20-minute walking distance (0.5mile and 1mile respectively) was measured using the point distance. This was achieved by finding the centroid of each green space and each census block group. The point distance from each block group to all green space within 0.5mile and 1mile was calculated. The total acreage of green space within the distance threshold was summarized and weighted using the total population for each census block group. This method provides insight on green space availability, potential use or disuse and overcrowding.

3.5.2 Quality of green space around Savannah

This study estimated the green space quality of the vegetation cover, using aerial imagery from the US National Agriculture Imagery Program (NAIP) to derive the Normalized Difference Vegetation Index (NDVI). For digital image analysis, several studies use supervised image classification and unsupervised image classification to determine tree canopy cover, and Normalized Difference Vegetation Index (NDVI) to examine vegetation health, as an indicator of quality green space ((Zhou and Kim., 2013; Nesbitt et al, 2019). The NDVI represents the health of green vegetation in the study area. NDVI ranges from -1 to 1 with negative values representing water, cloud and snow, values near zero representing bare soil and rock, and values near one representing healthy green vegetation.

$$\text{NDVI} = \frac{NIR - RED}{NIR + RED} \tag{ii}$$

This image analysis uses the Near Infrared (NIR) and visible red wavelength bands of the image, taking advantage of the high reflectance of green vegetation in the NIR due to spongy mesophyll and chlorophyll absorption in the red band. NDVI is determined by the band math of both wavelength bands. The aerial imagery was acquired during the growing season also known as "leaf-on" imagery in 2017 at one-meter ground sample distance (GSD). The imagery has a horizontal accuracy equivalent to six meters of ground control point (GCPs) at 95% confidence interval. The imagery is also collected in four spectral bands; blue, green, red, and near-infrared (NIR) with consideration for horizontal accuracy and tonal quality. Each image tile within the mosaic covers a 3.75 × 3.75-minute quarter quadrangle including a 200m buffer on its four edges. The NAIP imagery provides the best cost-free product for digital image analysis because it provides high-resolution imagery at high accuracy. In the study area, wetlands are dominant in the southeast but were not included in the study because they were inaccessible. However, the quality of vegetation cover in this region was assessed and included. Mean NDVI in each block group was calculated using zonal statistics to derive a quality index for each neighborhood.

3.5.3 Spatial accessibility to green space around Savannah

This study examines accessibility to green space using the gaussian based 2SFCA (two-step floating catchment area). The gaussian 2SFCA developed by Luo and Wang (2003) is an improvement on the gravity model. The initial gravity-based model developed by the authors accounts for distance decay based on a travel friction coefficient (β), while the 2SFCA is based on travel threshold time (d_0.). In analyzing spatial access to primary access care in Chicago, these authors found that at different travel thresholds, the gravity-based model gives higher accessibility to areas with poor access, involves more mathematical processes and produces less reliable results (Luo and Wang, 2003). The travel threshold time (d_0) in the 2SFCA only considers accessibility within the specified threshold which causes spatial smoothing and results in both factors having a directly proportional effect on each other. This method also considers nearby locations more accessible and farther locations less accessible based on a travel threshold but measures equal accessibility across a catchment area.

In his study on Black residential segregation, Dai (2010) modified this method by introducing the Gaussian function to assess spatial access to healthcare for a cancer study. This method attributes accessibility based on proximity to the specified resource within the catchment area. Hence, accessibility reduced with increasing distance from the resource/facility and vice versa. This method is suitable for this study because people are more likely to use a green space close to their residence but less likely to walk longer distances to use a green space far away.

Dai (2011) describes the process as follows; in the first step, for each green space location, all population locations within the specified threshold travel time (d_0) are sorted and the population is weighted using a Gaussian function (G). The sum of the weighted population within the catchment area is considered potential users of the green space, l. In the second step, for each population location, all green spaces within the threshold time d_0 from l are sorted. This forms the catchment for the population and reevaluates accessibility using the Gaussian function (G). Thus, the spatial accessibility at a specific location represents the sum of the ratio of green space to the population within the catchment area. The accessibility index is the ratio of supply (green spaces) to demand (population) based on the travel time and is represented:

$$Ai = \sum_{l\epsilon\{dil\leq d0\}} G\{d_{il}, d_0\}R_l \tag{iii}$$

Ai represents the acres of green space available for every 1000 people in each neighborhood,

$\boldsymbol{d_0}$ represents threshold time,

l represents all green spaces within the catchment area,

i represents the catchment area,

$\boldsymbol{R_l}$ represents the ratio of green space to the population,

and ***G*** denotes the Gaussian function

In this study, two thresholds, 10-minute and 20-minute walking distance, were selected to represent catchment size (d_0). Driving time was not considered because it does not effectively represent the capabilities of the population and assumes everyone in the population has access to a vehicle, which is unrealistic. In addition, assuming driving time could misrepresent potential social access of children and the elderly who are less likely to have vehicles. The 10-minute threshold was selected based on the Trust for Public Land recommendation of 10-minute walking distance to parks and green spaces. The study area is less urbanized, and the population is sparsely distributed compared to other study areas that use smaller distance thresholds (Dai, 2011). Hence, a 20-minute threshold was included to represent spatial variation across the study area and improve extremely low accessibility scores.

3.5.4 Green Space Index

The green space index is the dependent variable and was derived from the weighted overlay of the three variables, quantity, quality and accessibility. This method overlays the three variables which have been converted to raster using a common measurement scale and based on their level of importance. The three variables were weighted based on the threshold for each variable (10-minute and 20-minute). Hence, five rasters were rated and given an equal level of significance on an evaluation scale of 1 to 5 to adequately represent the variability of each variable. The weights were assigned based on natural breaks which considers the natural groupings in the data and identify class breaks that best group similar values and accounts for the differences between classes.

3.6 Independent variables/covariates

3.6.1 Race

Here, data on White (non-Hispanic), Black (non-Hispanic), Hispanic/Latino, and Asian and minority population was included in the analysis. White (non-Hispanic) makes up the majority of the population in the United States. Studies on spatial inequity in green space distribution have shown a significant relationship between this population and green space distribution. The study area's history highlights the marginalization of Black (non-Hispanic) population and shows that they were affected by early gentrification in Savannah (Hodder, 1993). The Hispanic/Latino population is one of the faster growing minority groups in the US and was often included to assess the spatial relationship between green space distribution and green space availability. Previous studies also observed a relationship between the Asian population and the distribution and spatial availability of green space (Dai, 2011). In addition, Hawaiian/Pacific Islanders and American Indians/Alaska natives are classified as minority population and included in this study to determine the relationship between green space inequities and an under-represented population.

3.6.2 Socioeconomic variables

The socioeconomic variables include median gross rent, median income, education, employment, median housing value and median housing age. The median gross rent represents the estimated monthly expense on housing/accommodation. This provides insight into the financial state and capacity of individuals and could explain the availability of neighborhood amenities. Median income provides insight into the earning capability of the population. The education variable considers only residents with higher education including associate degree, bachelor's degree, master's degree and doctoral degree. This variable was converted to percentages to show the percent of the population with higher education. By assessing this variable, the study aimed to show how the proportion of residents with higher education varies across the County and to determine if there is any relationship with the spatial distribution of green space. The employment variable is the percentage of the workforce (ages 15 to 64) employed either in the military or as civilians. Employment status can indirectly reflect the status of residents in a neighborhood in addition to their household income. The median housing value is the estimated value of each property and can help explain the local real estate market. It can also provide insights into the city's gentrification. The median housing age variable is useful to account for the historic component of the study area. This variable provides insight into the age of housing structure which could explain the spatial distribution of green spaces from a historic standpoint.

3.7 Data analysis

The green space index generated from the composite green space indicators of environmental inequities represents the dependent variable of interest in this study. Independent variables included race, median gross rent, median income, education, employment, median housing value and median housing age.

3.7.1 Spatial analysis

Spatial analysis includes multivariate regression to evaluate disparities in park availability and accessibility (Dai, 2011). The spatial component of the analysis uses geospatial analysis to highlight the importance of space, place and scale of analysis in the study as well as examine spatial variability of the data. The spatial analyses include point distance analysis to assess green space quantity, two-step floating catchment area analysis to determine spatial access to green space and NDVI analysis to measure green space quality. These variables were weighted spatially to generate a green space index. To test for spatial autocorrelation, Moran's I was used to identify spatial clustering of the variables in the study area.

3.7.2 Aspatial/statistical analysis

Aspatial analytical techniques employed include descriptive statistics, bivariate and multivariate regression (Rigolon et al, 2018; Dai, 2011). Descriptive statistics of all independent variables including mean, median, standard deviation, and range were summarized. Pearson correlation tests were applied to determine the bivariate correlation between green space inequity, race and socioeconomic variables. Multicollinearity among the independent variables were tested to identify a highly linear relationship (Wang 2005; You, 2016). The variance inflation factor (VIF) was used to determine variables with high multicollinearity and eliminate them from the regression analysis. The study includes variables with VIF less than or equal to 2.5 because the model does not show a strong relationship between the dependent and independent variables (Shaker & Ehlinger, 2014).

To generate the OLS model, the explanatory variables were standardized to provide a useful interpretation of the estimated observations and to avoid having different scales for the variables. For each census block group, standardized values for green space index, median gross rent, median income, education, employment, median housing value and median housing age White (non-Hispanic), Black (non-Hispanic), Hispanic/Latino, Asian and minority population were calculated. This was achieved by creating a deviation from the mean value and scaling the value by its standard deviation (Eq. i). This resulted in each variable having a mean of zero and a standard deviation of one. The standardized variables were then used to represent the dependent and independent variables.

$$z = \frac{x - \mu}{\sigma} \tag{iv}$$

Z = standard score

x = observed value

μ = mean of the sample

σ = standard deviation of the sample

Ordinary Least Square (OLS) was used to determine the association between green space inequity, race and socioeconomic factors in the study area (Dai, 2011; Maroko et al, 2009). The OLS model estimates the coefficient by reducing the sum of squared prediction errors. The model assumes the absence of bias in the regression equation (i.e., random errors have a mean of zero), the constant variance of random errors and normal distribution of random errors. But it does not consider spatial dependence (i.e., the effect of neighboring values). The data is then tested for spatial autocorrelation using Global Moran's I to assess spatial dependence. The regression model, Eq. (v) shows the regression between green space index and the control variables; median gross rent, median income, education, employment, median housing value and median housing age White (non-Hispanic), Black (non-Hispanic), Hispanic/Latino, Asian and minority population.

$$
\begin{aligned}
&greenspaceindex_i \\
&= \beta_1 mediangrossrent_i + \beta_2 medianincome_i + \beta_3 highereducation_i + \beta_4 employed_i + \beta_5 medianhousingvalue_i \\
&+ \beta_6 medianageofhousing_i + \beta_7 White_i + \beta_8 Black_i + \beta_9 HispanicLatino_i + \beta_{10} Asian_i \\
&+ \beta_{11} minority_i + \varepsilon_i
\end{aligned}
\qquad \text{(v)}
$$

Where the dependent variables $greenspaceindex_i$, green space index is a measure of green space quantity, quality and accessibility in each census block group i. The parameter for each independent variable is represented as $\beta_1 x_i$ (where x is the independent variable) in each census block group i. The standard error, ε accounts for the influence of the response variable (green space index) and other sources not included among the independent variable.

CHAPTER 4

FINDINGS AND RESULTS

4.1 Racial structure

The study area has a unique racial makeup with almost half of the population as White (non-Hispanic), followed closely by Black (non-Hispanic), while other races make up ~11.5% of the population (Table 4.1).

Table 4.1 Racial structure of residents in Chatham County, Georgia

Race	Composition
White	49.1%
Black	39.4%
Hispanic/Latino	6.3%
Asian	2.5%
Minority	2.7%

The White population was concentrated in the southeast and along the waterfront (Figure 7A), with an average of 48% in each block group and 36% in Savannah. In the historic district, the White population also makes up the majority of the population, comprising between 60-100% in Savannah downtown historic district and Victorian historic district, ~37% in Streetcar historic district and less than 15% in Cuyler Brownsville district. The Black population was concentrated in the center of Savannah with an average of 42% in each block group and 55% in Savannah. They also dominate the Cuyler Brownsville district with over 80% (Figure 7B). Hispanic/Latino residents were concentrated east of Garden City and west of Chatham County, in Savannah (Figure 8A). The majority of the Asian population resided in the outskirts of Savannah and dominates Garden City and the unincorporated area (Figure 8B). While other races were sparsely distributed around the study area with an average of 4% in each block group.

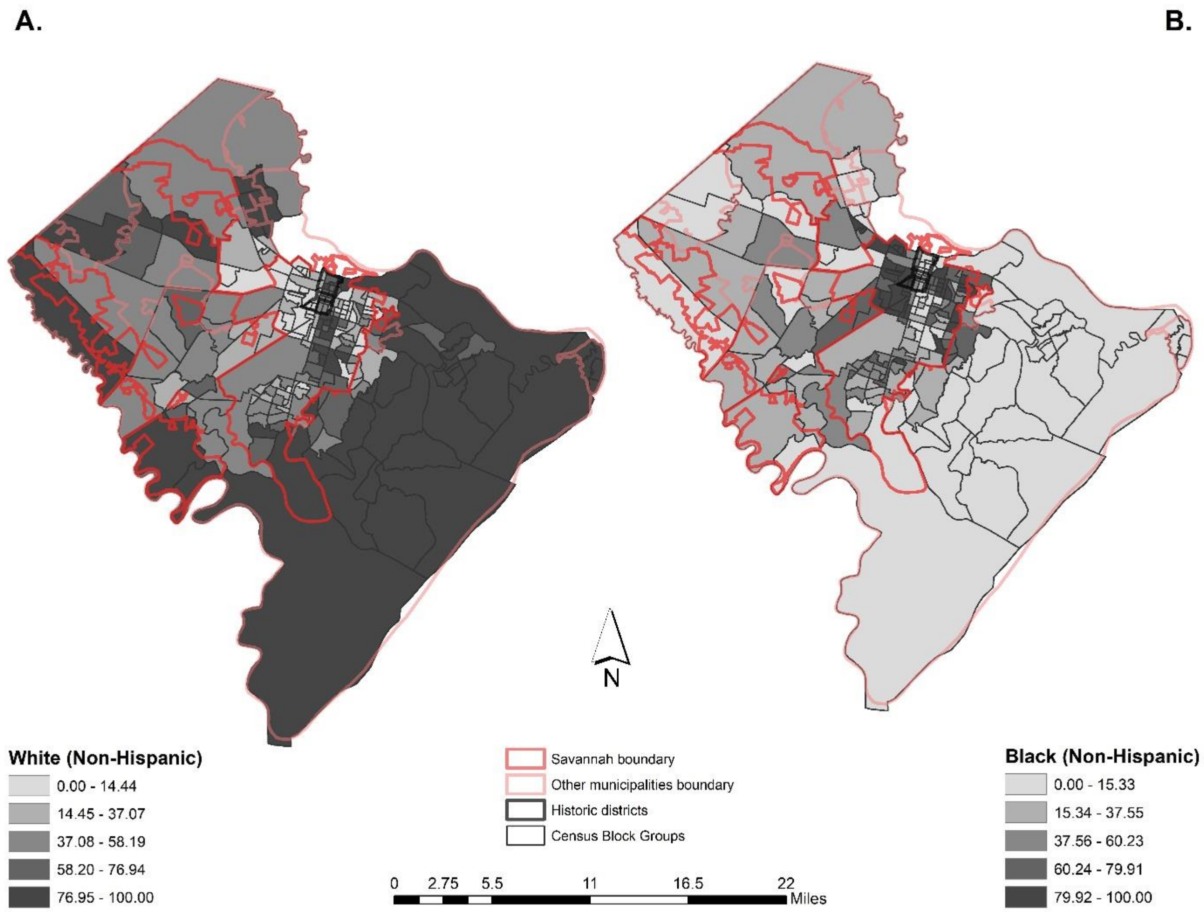

Figure 7: (A) Percentage of White (non-Hispanic) and (B) Percentage of Black (non-Hispanic) population at the census block group level in Chatham County, Georgia

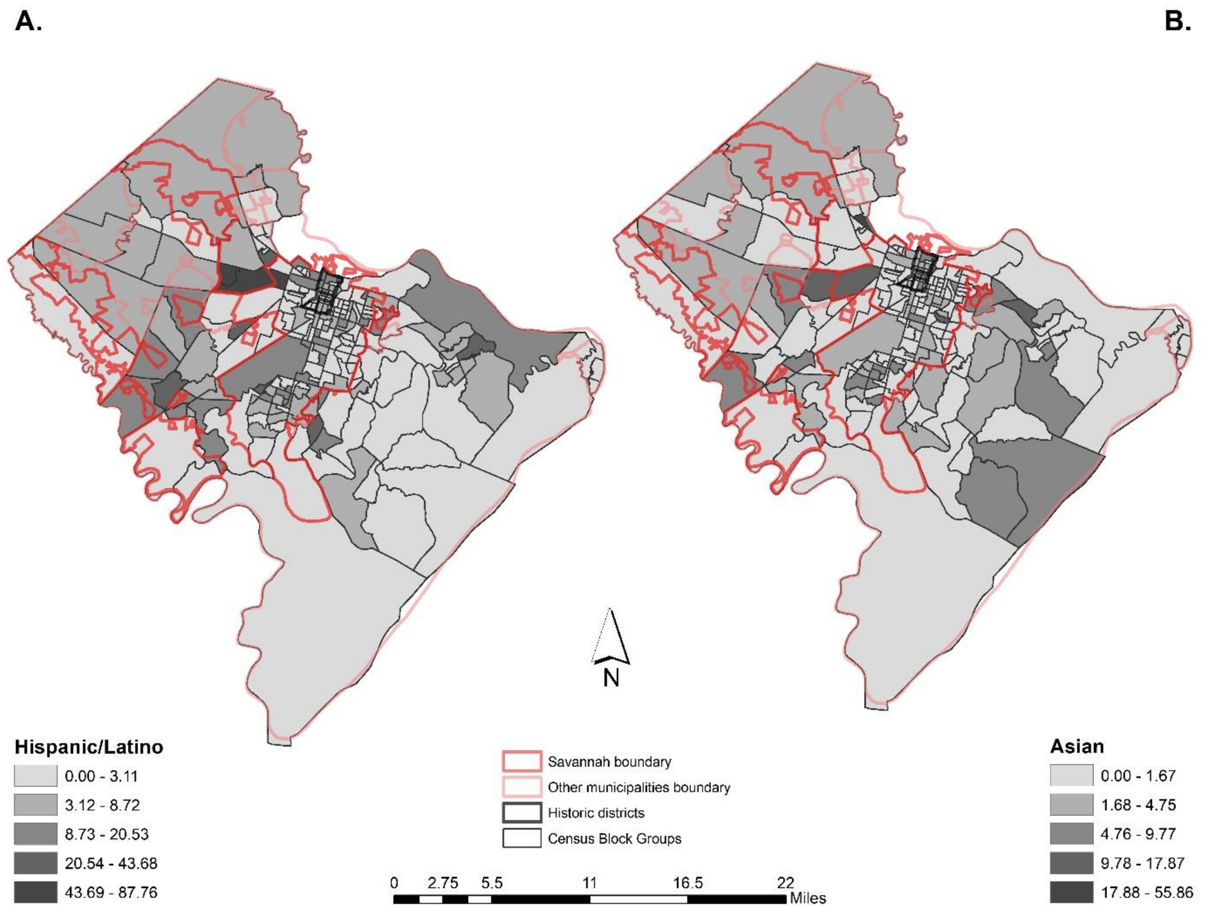

Figure 8: *(A) Percentage of Hispanic/Latino and (B) Percentage of Asian population at the census block group level in Chatham County, Georgia*

4.2 Socioeconomic characteristics

The average median gross rent for residents in Chatham County was $867 while the average in Savannah was about $60 higher than in other municipalities (Figure 9A). The median income of residents was highest in Richmond Hill, Port-Wentworth and the unincorporated area (i.e., Wilmington Island, Skidaway Island and Whitemarsh Island) and lowest in the city of Savannah (Figure 9B).

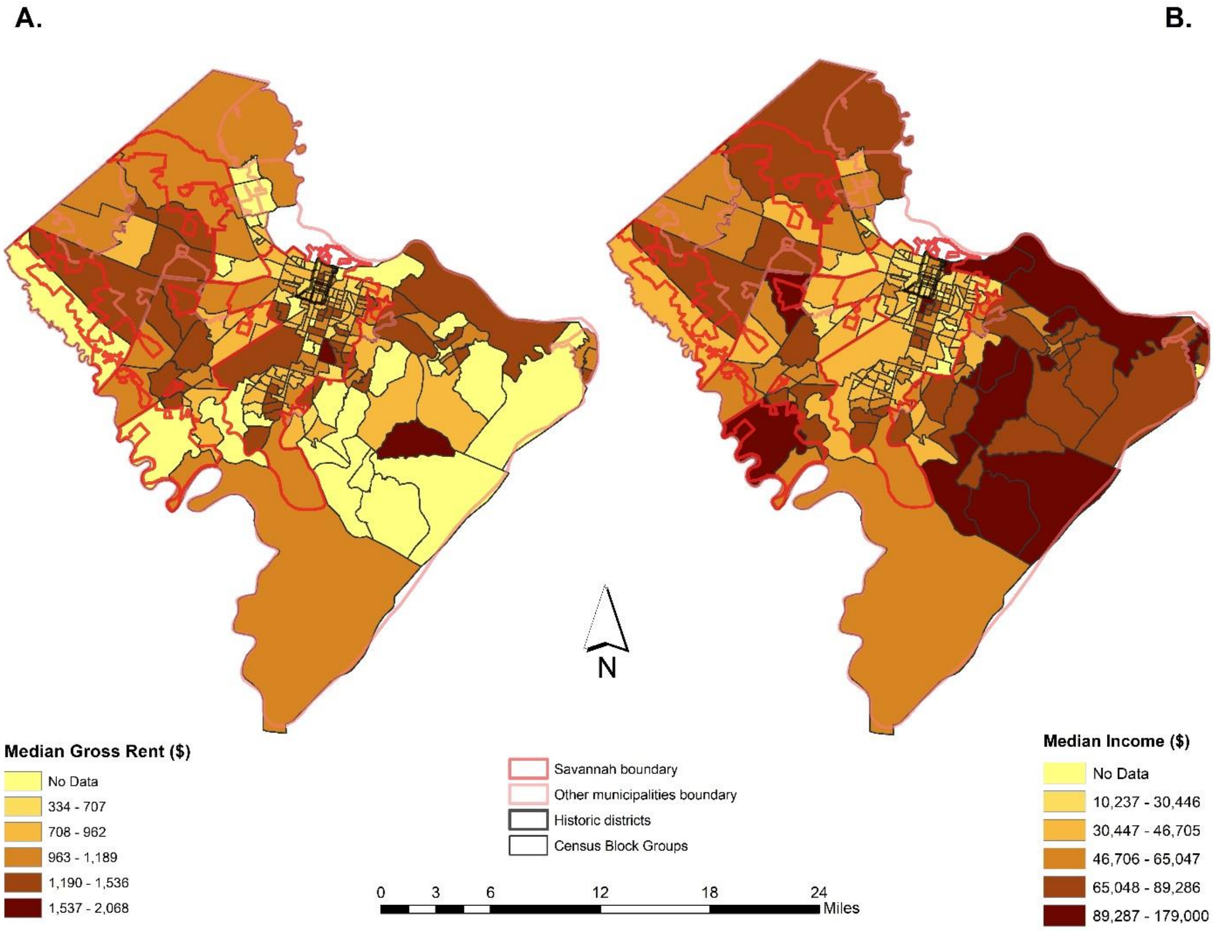

Figure 9: *(A) Median gross rent (in dollars) and (B) Median income (in dollars) of residents in Chatham County, Georgia*

Findings show that on average 36% of residents have higher education in each neighborhood with the majority residing southeast of the study area (Figure 10A). The labor force includes residents 16 years and older available for work. In this study, the employed labor force includes actively employed civilians and military personnel, which amounts for an average of 90% in each block group (Figure 10B).

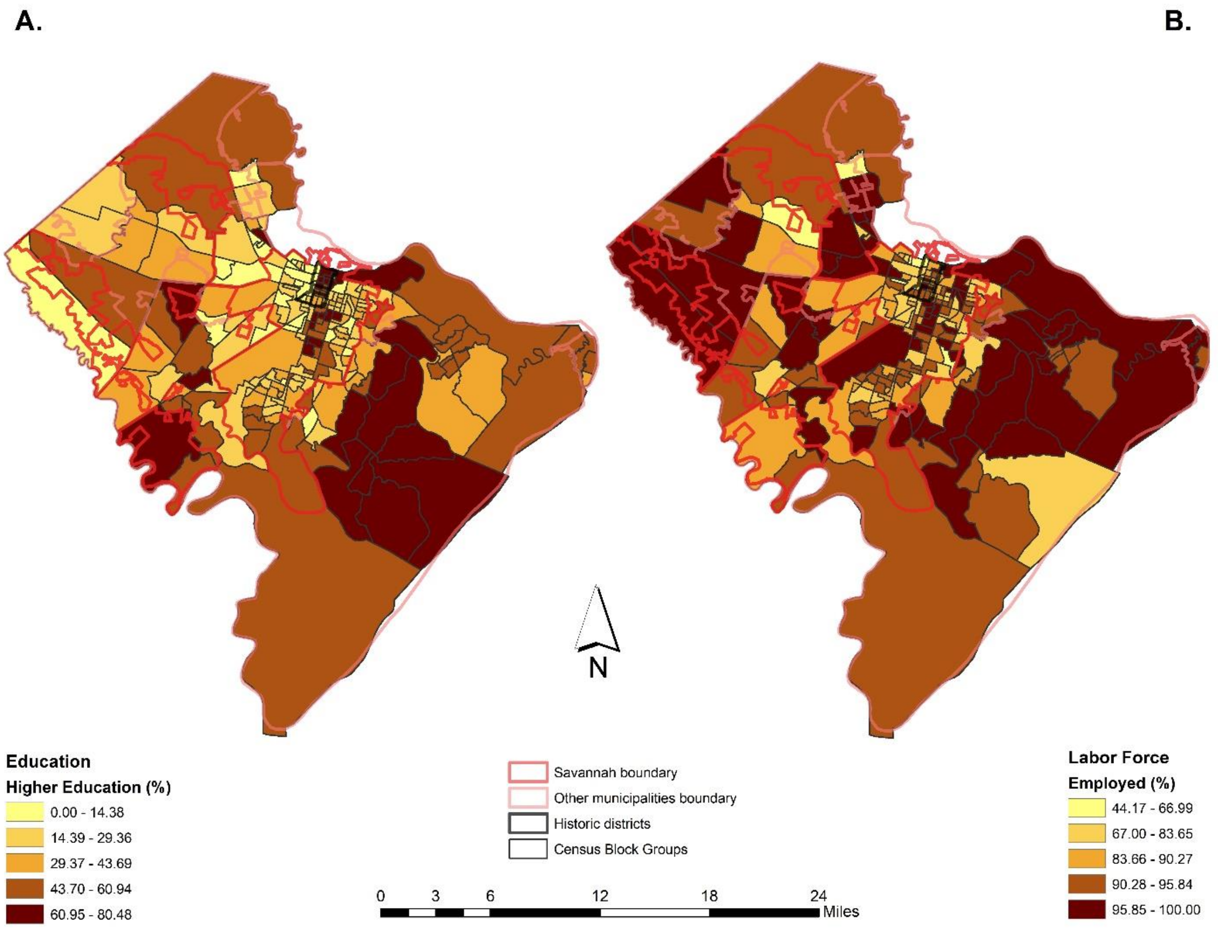

Figure 10: *(A) Percentage of Chatham County residents with higher education and (B) Percentage of labor force employed in Chatham County, Georgia*

Housing value follows the trend of median income, with the highest housing values observed in the historic districts of Savannah, an unincorporated area and southwest of Garden City, while the lowest housing values were found north of Garden City and southwest of Savannah (Figure 11A). The housing age was determined based on the median year the structure was built to date. The oldest houses were observed in Savannah while the newest houses were found in cities of Port Wentworth and Pooler (Figure 11B).

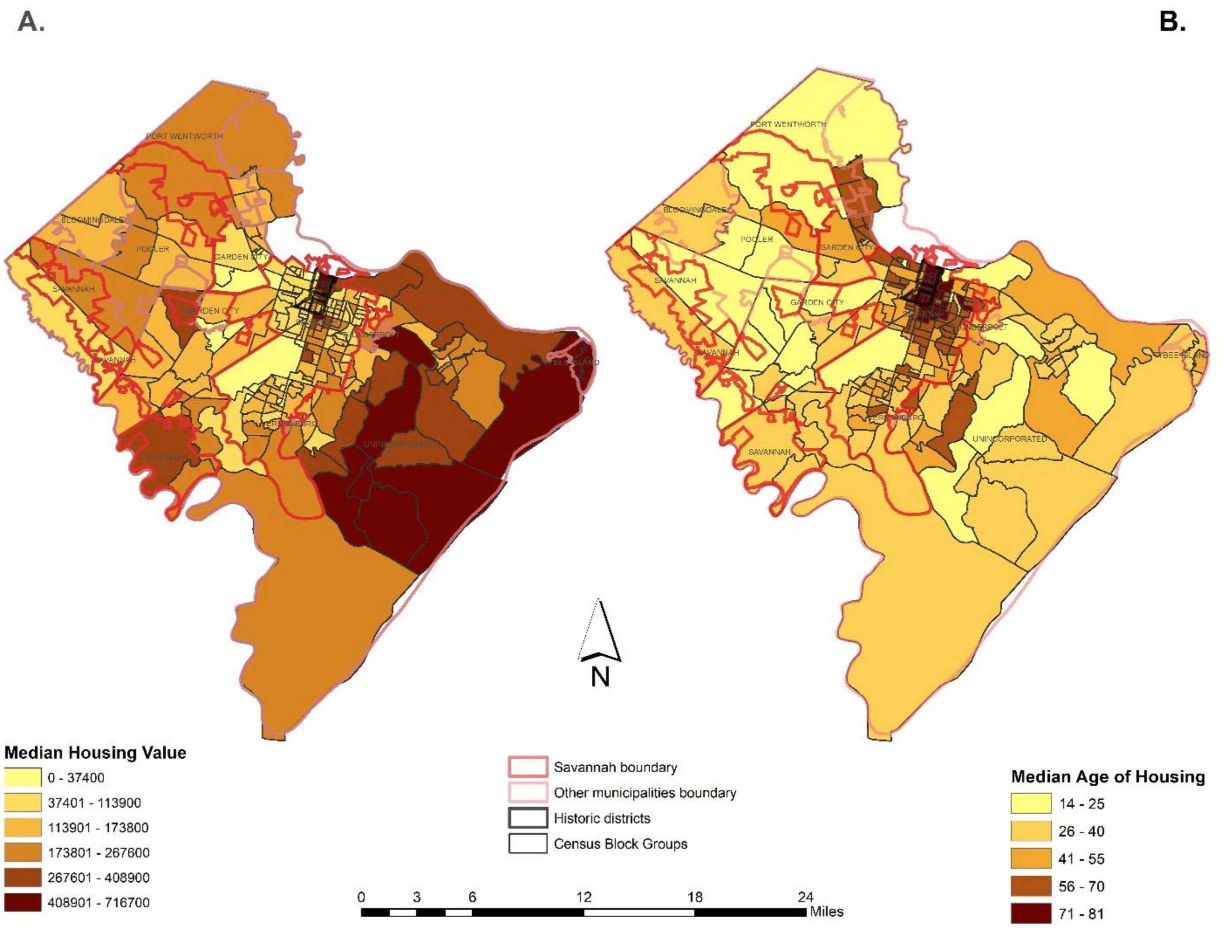

Figure 11: *(A) Median housing value (in dollars) of housing structures and (B) Median housing age of housing structures (in years) in Chatham County, Georgia*

4.3 Green Space Quantity

The quantity of green space varies significantly across several municipalities. The average green space size per block group was significantly smaller in Savannah compared to those of other municipalities (Table 4.2). However, the city has twice the number of green spaces in other municipalities and the highest acreage of green space compared to all other municipalities including the cities of Pooler, Port Wentworth, Garden City, Bloomingdale, Vernonburg, Tybee Island and Thunderbolt (Table 4.2).

Table 4.2: Distribution of green space across Savannah and other municipalities

Green space Distribution	Count	Acreage (acres)	Mean (acres)	Minimum (acres)	Maximum (acres)
Historic districts	39 green spaces	65.56	1.68	0.13	19.05
Savannah	136 green spaces	1185.13	8.71	0.05	260.77
Other municipalities	28 green spaces	874.74	31.24	0.11	334.19

The quantity index which measures green space acreage per population showed that Savannah residents had greater green space acreage per 1,000 residents compared to those in other municipalities (Table 4.3). Port Wentworth, Bloomingdale and Pooler had poor green space quantity for their residents' recreation. Findings also show no major difference in the quantity of green space within the historic district compared to the City of Savannah. The green space quantity was similar in Savannah and the historic districts at 10-minute and 20-minute walking distance, though the largest green spaces were found outside the historic districts (Table 4.3).

Table 4.3: Spatial distribution of green space quantity in Savannah and other municipalities

Quantity Index	Count	Mean (acres)	Minimum (acres)	Maximum (acres)
10-minute walking distance				
Historic districts	25 block groups	0.02	0	0.09
Savannah	128 block groups	0.02	0	0.32
Other municipalities	74 block groups	0.001	0	0.01
20-minute walking distance				
Historic districts	25 block groups	0.08	0.01	0.18
Savannah	128 block groups	0.08	0	0.67
Other municipalities	74 block groups	0.01	0	0.14

Generally, green space quantity increases as the threshold increases from the 10-minute to 20-minute walking distance (Figure 12). In the study area, disuse characterizes areas without green spaces within 10-minute and 20-minute walking distance, which reduces from 97.6% to 87.2% with the addition of the 20-minute threshold (Figure 12). However, only 14% of the population meet the NRPA national average of 9.5 acres per 1,000 people, highlighting the likelihood of overcrowded parks and playgrounds.

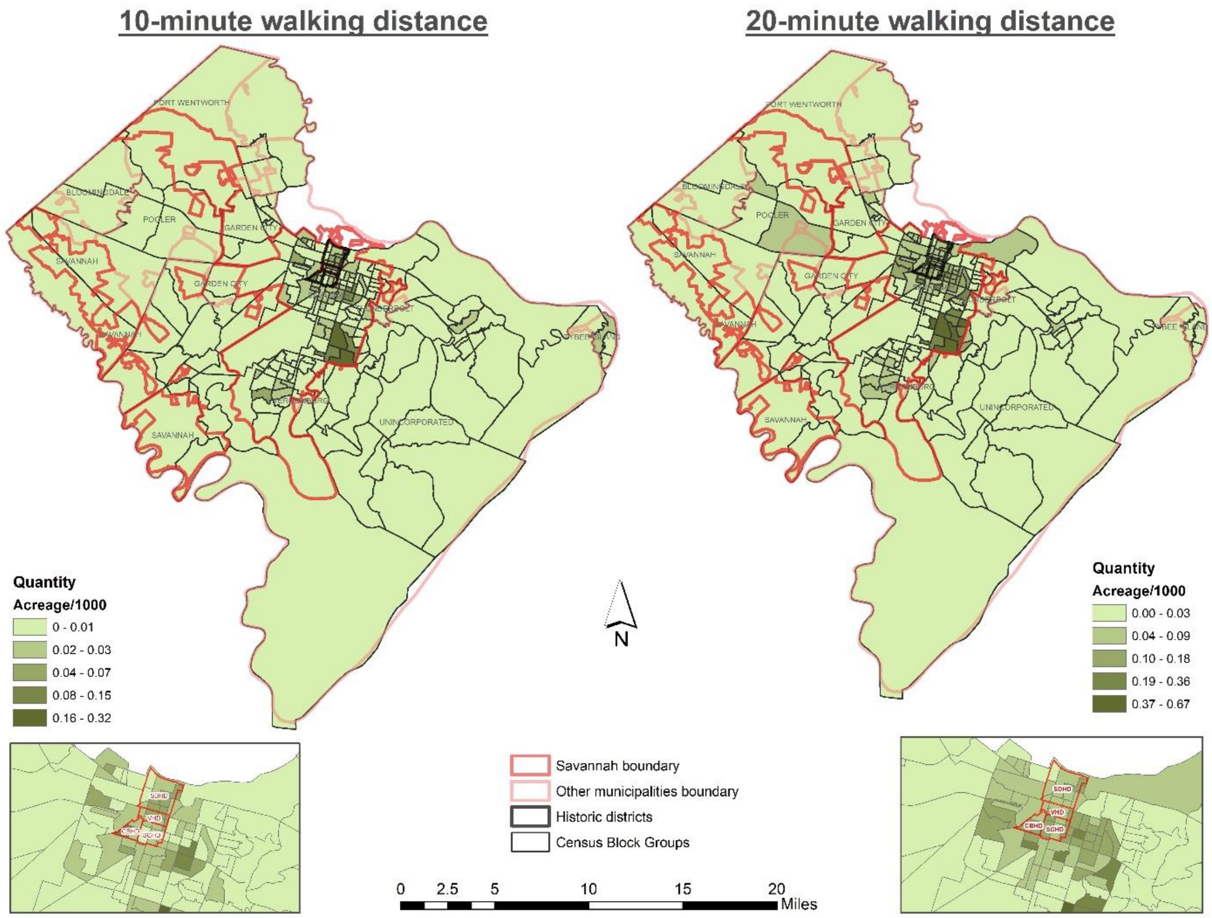

Figure 12: Quantity of green space in the city of Savannah and surrounding municipalities

In Savannah, among the largest green spaces were the Bacon Park golf course, Jennifer Ross soccer complex, Bacon Park area, Lake Mayer Park and Daffin Park. Compared to other municipalities, Savannah has a higher quantity of green space by count and average size. However, the largest green space in the study area; Al Henderson Golf Club spans about 334 acres and was in the unincorporated part of Chatham County. The unincorporated area also provides 11 other parks with an average size of 39.5 acres in each block group.

In Pooler, Tom Triplett Park was the largest green space by area, serving the residents, and supported only by Pooler Recreation Complex. Jaycee Park, Memorial Park and Park of 7 flags support the recreational needs of residents in Tybee island. In Bloomingdale, Taylor Park was the only available green space for residents. While in Port Wentworth, Porth Wentworth Recreational Complex and Port Wentworth Soccer Field were available for the population's use. In Garden City, among five parks serving the population's recreation needs, Bazemore Park stands out as the largest, spanning about 50 acres. The poor green space quantity in Thunderbolt was due to the availability of three parks; W.E Honey Park, Thomson Park and Nellie Johnson Park, which collectively span less than three (3) acres of land.

4.4 Green space quality

Mean NDVI was used to summarize green space quality for each census block in the study area. Green space quality index ranges from -0.33 to 0.29 representing various land covers from built-up space to green space, with an average quality index of 0.09 in the study area. The quality index was higher in Savannah compared to other municipalities though significantly lower within the historic districts (Table 4.4). The city of Savannah also has neighborhoods with the minimum green space quality in Chatham County. This finding was similar in the historic districts, while other municipalities had neighborhoods with the maximum green space quality.

Table 4.4: Spatial distribution of green space quality in Savannah and other municipalities

Quality Index	Count	Mean	Minimum	Maximum
Historic districts	25 block groups	0.04	-0.2	0.15
Savannah	128 block groups	0.09	-0.2	0.22
Other municipalities	74 block groups	0.08	-0.3	0.29

Neighborhoods with a high green space quality represent healthy vegetation and dense tree cover, while neighborhoods with low green space quality represent non-tree features and sparse vegetation cover. Bloomingdale and Pooler had the highest green space quality, followed closely by Port Wentworth and

Tybee Island. The city of Savannah had good green space quality though the quality of green space in the historic districts was lower than in other Savannah neighborhoods (Figure 13). However, the lowest green space quality was observed in neighborhoods in southeast Chatham County.

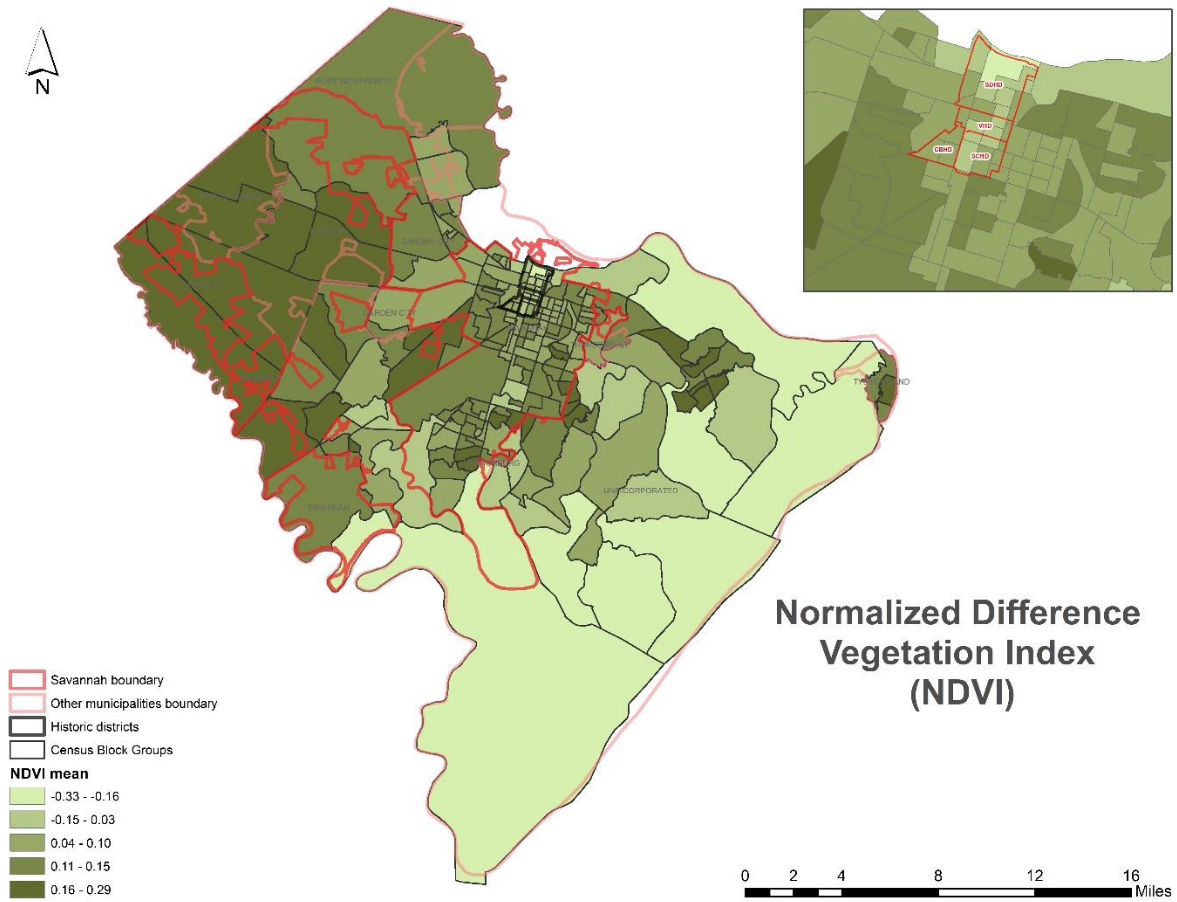

Figure 13: *Quality of green space in the city of Savannah and surrounding municipalities*

4.5 Green space accessibility

The average distance to green space in Chatham County was 5.9 miles, which represents approximately 2-hour walking distance. However, the average access to green space in the study area was significantly higher than the national average (Zhang et al, 2011). Generally, at 10-minute walking distance, accessibility was low in the study area with an average index of 6.12. Because this is a population weighted method, accessibility in every neighborhood is a function of the total population. The population in other municipalities was relatively low compared to the population in the city of Savannah where the population was dense. Therefore, compared to other municipalities, there was poor accessibility in the city of Savannah (Figure 14).

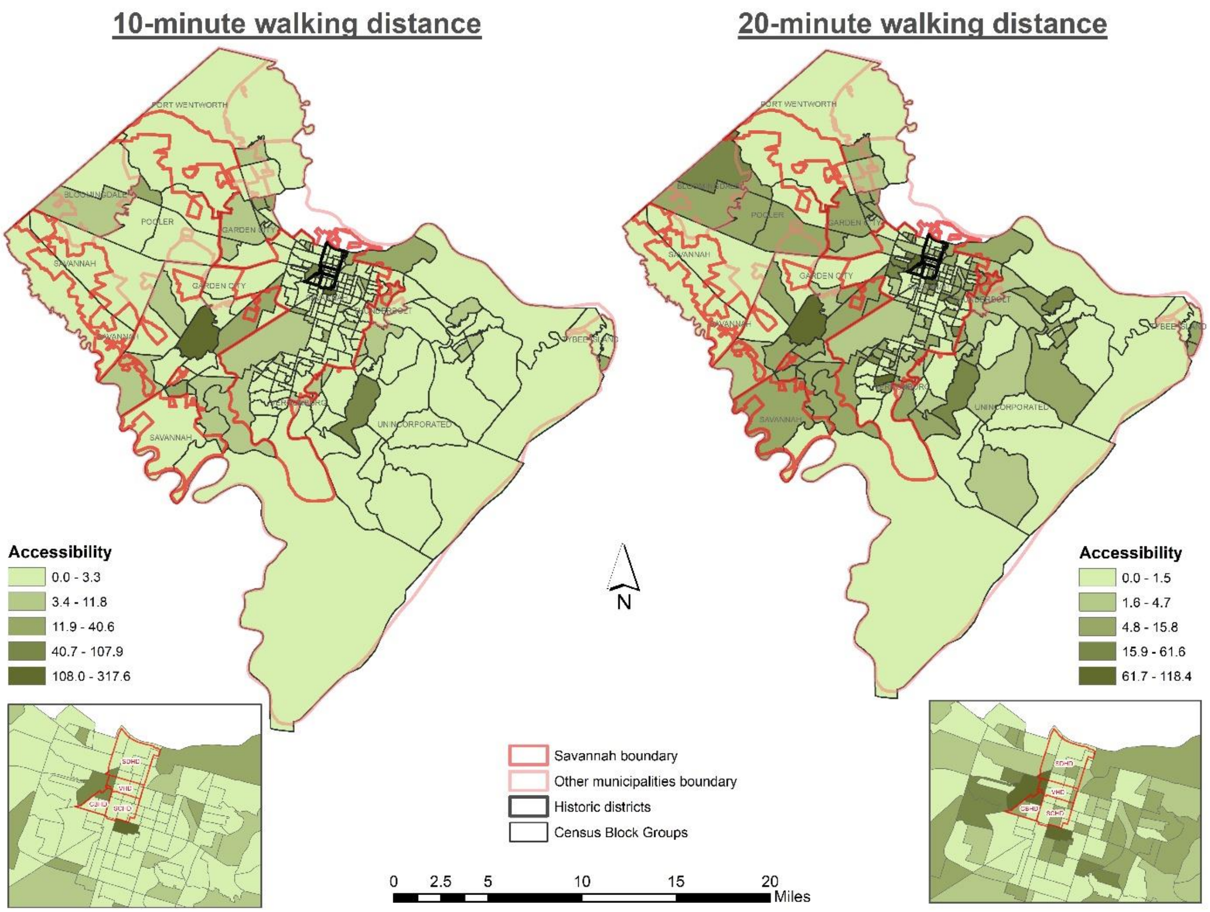

Figure 14: *Accessibility to green space in the city of Savannah and surrounding municipalities of Chatham County, Georgia*

In addition, the average size of green space in Savannah is 8.7 acres compared to 31.2 acres in other municipalities. The maximum accessibility in other municipalities was observed at 10-minute walking distance but 20-minute walking distance in Savannah because this population-weighted method considers population around each catchment area. The population increases with increases in the catchment area size, and in turn reduces accessibility in that area. Findings show that on average, accessibility was significantly higher in other municipalities than in Savannah at 10-minute walking distance, but this gap closes as the threshold increases to 20-minute walking distance (Table 4.5). At 20-minute walking distance, similar accessibility was observed across all municipalities. On the other hand, accessibility was higher in the historic districts at both walking distances compared to the city of Savannah, but accessibility in the historic district decreases as the catchment area increases.

Table 4.5: Spatial accessibility of green space in Savannah and other municipalities

Accessibility index	Count	Mean	Minimum	Maximum
10-minute walking distance				
Historic districts	25 block groups	14.13	0	228.56
Savannah	128 block groups	4.36	0	228.56
Other municipalities	74 block groups	9.16	0	317.62
20-minute walking distance				
Historic districts	25 block groups	12.13	0	118.42
Savannah	128 block groups	7.31	0	118.42
Other municipalities	74 block groups	7.22	0	98.03

4.6 Green Space Index

Green space quantity, quality, and accessibility indices for each block group were weighted equally and composited into one measure called green space index. A higher green space index indicates lower green space inequity and vice versa. Here, green space index shows an average of 2.88 (Table 4.6).

Table 4.6: Summary statistics of spatial inequity indicators and green space index

	Mean	SD	Minimum	Maximum
Quantity (*10-minute distance*)	0.01 acres	0.03 acres	0	0.32 acres
Quantity (*20-minute distance*)	0.05 acres	0.1 acres	0	0.67 acres
Quality	0.09	0.09	-0.33	0.29
Accessibility (*10-minute distance*)	6.12	29.3	0	317.62

Accessibility (*20-minute distance*)	7.28	16.5	0	118.42
Green space Index	2.88	0.93	1	5

The City of Bloomingdale has the best green space in the study area based on an average index of 3.5. The city of Savannah and Tybee island follow closely with a mean of 3, while Pooler has an average of 2.8 and Garden City a mean of 2.7. Municipalities with low green space index include Thunderbolt, Vernonburg, Port Wentworth and the unincorporated area (Figure 12). However, the overall green space index is similar in the city of Savannah and its historic districts.

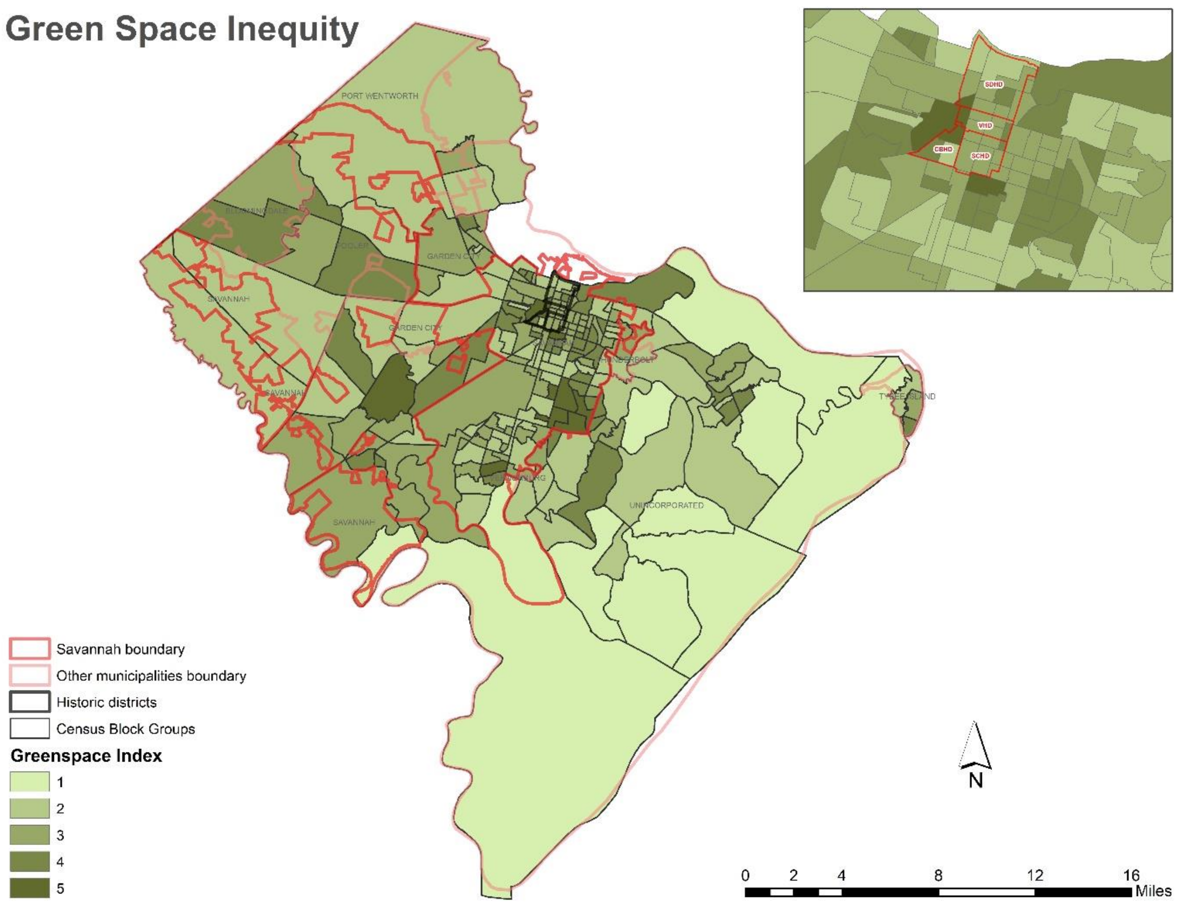

Figure 15: *Green space index ((higher index representing better green space) based on the quantity, quality and accessibility to green space in Chatham County, Georgia*

4.7 Descriptive statistics for variables

The descriptive statistics provide a quantitative summary of the data set (Table 4.7). The statistics show the measure of central tendency; mean and measure of spread including the range of values and standard deviation.

Table 4.7: Summary statistics of variables for census block groups in Chatham County

Variables	Mean	Standard deviation	Minimum	Maximum
Population	1,413.4	1,816.23	237	23,196
Population density(/km^2)	1330	1197.71	3.64	6116.64
Percent White	48.06%	32.53%	0%	100%
Percent Black	42.07%	33.65%	0%	100%
Percent Asian	2.05%	4.75%	0%	55.86%
Percent Hispanic/Latino	5.58%	10.14%	0%	87.76%
Percent Minority	2.24%	3.28%	0%	21.49%
Median gross rent ($)	$867.05	$418.89	$334	$2068
Median income ($)	$50,353.16	$24,479.7	$10,237	$179,000
Higher Education (%)	36.23%	19.92%	0%	80.48%
Employed Population (%)	90.37%	8.77%	44.17%	100%
Median housing value ($)	$190,921.78	$128,139.17	$32,200	$716,700
Median age of housing (years)	49.04	18.21	14	81

4.8 Statistical analysis

The study includes bivariate correlation and multivariate regression analyses. Eleven variables at the census block group level were used to describe the socioeconomic status and racial structure of the population. Median income and median gross rent were measured in dollars. Median housing age was in years, while other variables were measured in percentage. Table 4.8 shows the bivariate correlation between the green space index and the 11 variables. At 95% confidence interval, poorer green space was significantly associated with the median income while better green space was significantly correlated with the median age of housing and median gross rent. Other variables did not have a significant relationship with the green space index.

Table 4.8 Pearson's bivariate correlation between green space index, racial and socioeconomic variables

Variables	Green Space Index	Median gross rent ($)	Median income ($)	Higher Education (%)	Employed Population (%)	Median housing value ($)	Median age of housing ($)	White	Black	Hispanic/ Latino	Asian	Minority
Green Space Index	1											
Median gross rent ($)	.157*	1										
Median income ($)	-.185**	-.105	1									
Higher Education (%)	.076	.065	.665**	1								
Employed Population (%)	-.066	.052	.358	.395**	1							
Median housing value ($)	-.117	-.064	.597	.770**	.294**	1						
Median age of housing (years)	.214**	.057	-.307**	-.063	-.176*	.021	1					
White (non-Hispanic) (%)	-.082	-.087	.651**	.707**	.400**	.670**	-.151*	1				
Black (non-Hispanic) (%)	.113	.070	-.605**	.670**	-.443**	-594**	.215**	-.940**	1			
Hispanic/Latino (%)	-.074	-.018	-.045	-.157*	.118	-173*	-.165*	-.096	-.203	1		
Asian (%)	-.060	.094	-.034	.259**	.147*	.096	.011	.097	-.229**	-.018	1	
Minority (%)	-.023	0.64	-.062	-.029	-.005	.153*	-.211**	-.116	.026	.034	-.007	1

**. Correlation was significant at the 0.01 level (2-tailed).

*. Correlation was significant at the 0.05 level (2-tailed)

The multivariate regression model includes an Ordinary Least Squares (OLS) model to determine the relationship between the green space index and the 11 variables. The multicollinearity test excluded White (non-Hispanic), minority and higher education variables due to high linearity (Table 4.9).

Table 4.9 Multicollinearity test

Variable	VIF
Median gross rent	1.032
Median income	2.216
Employed population	1.297
Median housing value	2.151
Median age of housing	1.235
Black (non-Hispanic)	2.489
Hispanic/Latino	1.256
Asian	1.146

The Ordinary Least Squares (OLS) model shows the linear relationship between the green space index and the control variables; median gross rent, median income, employment, median housing value and median housing age, Black (non-Hispanic), Hispanic/Latino, and Asian (Table 4.10).

Table 4.10 Multivariate analysis of green space index using race and socioeconomic status as control variables.

The table presents regression results for the model:

$$greenspaceindex_i = \beta_1 mediangrossrent_i + \beta_2 medianincome_i + \beta_3 employed_i + \beta_4 medianhousingvalue_i + \beta_5 medianageofhousing_i + \beta_6 Black_i + \beta_7 HispanicLatino_i + \beta_8 Asian_i + \varepsilon_i$$

Variable	Coefficient	Significance	Standard error
Median gross rent	.141	**.044***	.070
Median income	-.131	.200	.102
Employed population (%)	.013	.872	.078
Median housing value	-.116	.248	.100
Median age of housing	.182	**.017***	.076
Black (non-Hispanic)	-.121	.263	.108
Hispanic/Latino	-.096	.214	.077
Asian	-.100	.174	.073

R-squared= .098

*. significant at the 0.05 level ($p < 0.05$)

Global Moran's I was computed to test for spatial autocorrelation and measure the independence of observations by plotting the standard residuals of the OLS model. Moran's index of 0.010 and z-score of 1.365 represented a random pattern. The absence of spatial dependence makes the OLS model valid, hence there was no need to adopt spatial lag or spatial error models.

The OLS model showed a statistically significant relationship between two socioeconomic variables and green space index. This analysis showed that median gross rent and median housing age were associated with green space accessibility, quantity and quality. The estimated coefficient of median gross rent showed a significant positive relationship with green space index ($p < 0.05$, Table 4.9). When median gross rent increases by one standard deviation ($418.89), green space index goes up 0.141 standard deviation. Also, the estimated coefficient of median housing age showed a significant positive relationship with green space index ($p < 0.05$, Table 4.9). When median housing age increases by one standard deviation

(18.21 years), green space index increases by 0.182 standard deviation. However, contrary to expected findings, there was no significant relationship between racial structure and green space index.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 Research Summary

Green space inequities have implications on public health, environmental sustainability and environmental justice. This research adopted a unique approach to measure spatial inequities based on quantity, quality, and accessibility to green space by residents. These measures were combined to create an index that defines inequities because the lack of one or more of these variables could affect the social function of a green space and the recreational benefit of residents.

This approach has a range of benefits. Firstly, the quantity measure which uses Euclidean distance to determine acreage of green space available for the population within selected walking distances promotes pedestrian access to green space and advocates for certain members of the population like children, the elderly, and the immobile (Talen, 2003; Boone et al, 2009). In addition, this approach supports the green space needs of residents beyond their geographic boundary. Secondly, green space quality measured by mean NDVI accounts for the health and type of vegetation (Nesbitt et al, 2019) while low NDVI represents non-tree features including built-up spaces and water. This approach makes it possible to assess the potential recreational value of tree cover in a green space and around the neighborhood and provides insight to improve green space distribution (Nesbitt et al, 2019). Thirdly, the Gaussian based 2SFCA function creates a realistic accessibility model to examine the interaction between green space and population (Luo and Wang, 2003; Dai, 2011). This approach uses a catchment area which makes it easy to adopt walking, biking or driving distance. It also identifies neighborhoods with inadequate green space based on acreage and population density. This method can also be applied to target certain populations such as children and the elderly by using their population. Besides, creating a green space index is a wholistic approach that considers these measures as vital to green space use and access.

In the city of Savannah, green spaces were a lot smaller in size on average compared to other municipalities. However, Savannah had the highest count of green space among all municipalities, therefore better green space quantity both at 10-minute and 20-minute walking distances. The maximum green space quantity was observed in Savannah while findings showed that green space quantity in the city of Savannah and its historic districts were similar. These results showed that historic city planning in the city of Savannah had a positive influence on green space quantity. This implies that green spaces do not necessarily have to cover a wide expanse but can be as adequate for residents if placed in small pockets around the city. Similarly, Boone et al. (2009) showed that residents in Baltimore, Maryland had good access to parks due to the spatial distribution of parks in the city.

Green space quality was highest around the northwest of the study area, in Bloomingdale, Port Wentworth, Tybee Island and Pooler and lowest in the south including unincorporated Chatham County. This was explained by Islands on the coast covered with a large expanse of wetland. The quality of green space in Savannah was higher than those in the historic districts. This was because the historic districts were highly developed and commercialized compared to the rest of the city, with a large expanse covered by built-up areas including historic structures and monuments.

While the average accessibility to green spaces in Chatham County was higher than the national average at 10-minute walking distance, the city of Savannah has relatively low accessibility compared to all other municipalities. The population was denser in the city and green spaces were a lot smaller on average compared to findings in other municipalities like the unincorporated part of Chatham County which holds the largest green space in the area. However, at 20-minute walking distance, average accessibility was similar in Savannah and other municipalities. At the larger threshold, accessibility in Savannah improves because the larger green spaces in surrounding municipalities compensate for the smaller ones in the city. When historic districts were considered, accessibility was higher in the historic district because of the even distribution of green spaces on each block (Moore et al, 2008).

The green space index shows green space inequities for each block group and within each municipality. The city of Bloomingdale had the highest green space index overall, an expected finding considering quantity, quality, and access to green space was also high in its neighborhoods. The city of Savannah and Tybee Island also have better green space and fewer inequities compared to other municipalities like Pooler, Garden City and Thunderbolt. The lowest green space indices were observed in Vernonburg and Port Wentworth because the quantity, quality and access to green space in these municipalities were poor.

5.2 Research Implications

This study evaluated spatial inequities of green space among different racial and socioeconomic groups. Among several socioeconomic variables examined, median gross rent was observed to significantly affect spatial inequity. Findings showed that neighborhoods in the study area with higher median gross rent had better green space compared to areas where residents pay relatively lower rent. This highlights the impact of a resident’s spending capacity for housing on their ability to have adequate, good and accessible green space (Talen, 1997).

The study also found that neighborhoods with older housing structures have better green spaces than areas with otherwise more modern houses. Similarly, in their Baltimore study, Grove et al. (2006) observed that the housing age was significantly associated with the distribution of vegetation around the city. This finding was significant for Chatham County given the historical development of Savannah. Green spaces in Savannah were laid out in the grid from the early 1700s when James Oglethorpe executed the city plan. Hence, older housing structures especially in the historic districts were laid out in line with green spaces ensuring ease of access and adequate recreational spaces for the urban residents. This provides insight on why green inequities were much lower in the city of Savannah compared to most municipalities and why the accessibility to green spaces was significantly higher in the historic districts.

Findings from this study have important environmental and policy implications. Several organizations advocate the 10-minute walking distance but even in a historically planned city like

Savannah, most residents cannot access green space at a 10-minute distance. This calls for the attention of city planners and policy makers to recognize the need for more green spaces and improve access to recreational facilities by providing new parks, playgrounds, and sports fields.

5.3 Study limitations

The study computed a green space index to examine green space inequities based on Euclidean distance to green spaces, the health of vegetation and tree cover and accessibility of green space. However, several limitations were encountered in this research which could be addressed in future studies. Firstly, point distance analysis adopted Euclidean distance, but future study may improve this by using network distance along pedestrian walkways and bike lanes to represent the travel means. This will address the needs of both pedestrians and cyclists for urban green space. Secondly, the quality index only considers the health of the vegetation. An assessment of green space facilities, attractions and tree canopy cover will be necessary to comprehensively determine the quality of green space (Moore et al, 2008). In addition, some variables had missing data for several neighborhoods including the median gross rent. This could potentially affect the result which may be improved by efficient data collection from the American Community Survey (ACS).

5.4 Conclusion

In conclusion, this research introduced a green space index to represent green space inequities in Chatham County, Georgia. The findings provide information to identify areas with inadequate green space and to promote environmental justice in green space provision. The green space index created was intended to promote the provision of an all-inclusive green space for future purposes. Furthermore, green spaces should be provided in new neighborhoods along with modern housing to reduce inequities associated with housing age.

This study contributes to environmental justice in two major ways. Firstly, the research promotes environmental justice scholarship by examining green space inequities as an environmental justice issue. While previous studies have considered issues relating to pollution and human health, recent scholarship has grown to include green space inequities. This study contributes to the growing body of research and is also geared towards promoting public health. Secondly, the study highlights the importance of historical development and city planning in understanding environmental justice, an aspect only few studies have considered (Boone et al, 2009; You, 2016; Tu et al, 2018). For a unique case study like Savannah, this study draws attention to the role of city planning on environmental equity. This is evident in high accessibility to green space observed in the historic districts compared to other neighborhoods.

Urban planning plays a significant role in understanding green space inequities. Contrary to similar studies, no significant relationship was observed between racial structure and green space index in the study area. Irrespective of gentrification and preservation movement that occurred around Savannah in the 1970s, the historic city plans ensured green spaces were well distributed across the city. This highlights the importance of historic city plans in not only ensuring environmental justice but also in understanding green space inequities where they occur.

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